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ESTIMATION OF IRRIGATION WATER REQUIREMENTS OF SRIKAKULAM DISTRICT, ANDHRA PRADESH USING BLANEY-CRIDDLE AND PENMAN-MONTEITH REFERENCE EVAPO TRANSPIRATION

YERRAMSETTY ABBULU[1] & G. V. R. SRINIVASA RAO[2]

[1]Associate Professor, Department of Civil Engineering, AUEC (A), Andhra University, Visakhapatnam, Andhra Pradesh, India

[2]Professor, Department of Civil Engineering, AUEC (A), Andhra University, Visakhapatnam, Andhra Pradesh, India

ABSTRACT

The irrigation development in Srikakulam, a north coastal district of Andhra Pradesh is mainly dependent on tanks. But during the past five decades the district recorded a negative growth rate of irrigation. This necessitated a systematic study to be conducted on irrigation water requirements considering all principal crops grown in the district. Irrigation systems can be improvised by taking into consideration various climatic factors and local conditions. Selection of the crop coefficient, the relationship between the Reference Evapo transpiration (ETo) and crop water requirement of specific crops are certain important factors in determining the irrigation needs of a particular place. The Blaney-Criddle method is one such method incorporating all such practical procedures and necessary conditions for obtaining a reasonable estimate of irrigation water requirements. Similarly, The Penman-Monteith method is also a widely recommended method to determine ETo. In the present study, ETo's are obtained using both these methods by taking into consideration various local conditions. These ETo's are further used to estimate the irrigation water requirement of the study area and compared with that of the existing availability of water resources of the district. It is observed that the tanks, a major source of irrigation in Srikakulam district augment only 26.09% of the total irrigation water requirement.

KEYWORDS: Reference Evapo transpiration (ETo), Blaney-Criddle Method, Penman-Monteith Method, Irrigation Development

NOMENCLATURE

ETo =reference evapo transpiration ($mmday^{-1}$)

R_n= net radiation at the crop surface ($MJ\ m^{-2}\ day^{-1}$)

G =soil heat flux density ($MJ\ m^{-2}\ day^{-1}$)

T =air temperature at 2m height (°C)

u_2= wind speed at 2m height ($m\ s^{-1}$)

e_s =saturation vapour pressure (kPa),

e_a= actual vapour pressure (kPa)

e_s-e_a= saturation vapour pressure deficit (kPa)

D= slope vapour pressure curve ($kPa\ °C^{-1}$),

γ= psychometric constant (kPa $°C^{-1}$).

W_r=Net irrigation requirement at the field level.

= (Consumptive use-effective rainfall land preparation needs +Percolation losses) (mm/month)

$W_r = (C_u – E_r) + 250$ for Paddy (mm/month)

$W_r = (C_u – E_r)$ other than Paddy (mm/month)

Cu = Consumptive Use

= ETo x K_c (mm/day)

K_c= Crop-coefficient

ETo = Reference evapo transpiration calculated using Penman – Monteith method (Cropwat 8.0)

and E_r = effective rainfall

ETo = Reference Evapo transpiration (mm/day)

K_c = Crop Coefficient

E_T Crop = the crop water need (mm/day)

SAT = Water needed to saturate the soil or land preparation (mm) (200 mm for rice and zero for other Principal crops)

PERC = the percolation and seepage losses (4 mm/day for clay soils, 8mm/day for sandy soils and 6mm/day for mixed soils)

WL = the amount of water need to establish a water layer during transplanting or sowing and maintained throughout the growing season (100mm for paddy and zero for other Principal crops).

P_e= the monthly effective rainfall.

INTRODUCTION

Irrigation systems can be improvised by taking into consideration various climatic factors and local conditions. In addition, it is also necessary to understand the suitability of the region for different types of crops within the framework of the climatic conditions and different types of irrigation systems of the region i.e. minor, medium and major, in order to achieve the best possible results in terms of agricultural production.

Selection of the crop coefficient, which gives relationship between the Reference Evapo transpiration (ETo) and crop water requirement of specific crops (Shankar Reddy G.H. et al[3] 1985) is most important in determining the irrigation needs of a particular place. Various climatic factors should be considered in the determination of crop coefficients. The FAO Blaney-Criddle method (FAO-BC) is one such method incorporating all such practical procedures and necessary conditions for obtaining a reasonable estimate of irrigation water requirements (Richard G. Allen et al[1]. 1986). The reference evapo transpiration (ETo) represents the potential evaporation of well watered grass crops. The water needs of the crops other than grass crops are directly linked to various climatic parameters. The Penman-Monteith method is recommended as the appropriate combination method to determine ETo using the climatic data of temperature, humidity, sunshine and wind speed (FAO irrigation and drainage paper No:56, Richard G. Allen et al[2]. 1998). However, some of

these variables, especially solar radiation, are often missing in these calculations. To overcome these problems, various procedures to estimate ETo with missing climatic data are proposed as part of the FAO-PM methodology and it is important to assess the accuracy of these procedures for different climatic conditions (Zornitsa Popova et al[5]. 2006). CROPWAT 8.0 and the ETo evaluated using Penman-Monteith formula can be effectively used for the calculation of crop water and irrigation requerements (Waseem Raja[4] 2010). In line with these observations, an attempt is made in this present work to estimate the irrigation water requirements of the study area using Blaney-Criddle and Penmam-Moneteith ETo's.

METHODOLOGY

Study Area

Srikakulam, the northern most coastal district of Andhra Pradesh located between 18^0 20^1 N and 19^0 10^1 N latitudes and 83^050^1 E and 84^0 50^1 E longitude is considered as study area. The district had three distinct physiographic areas viz., coastal planes, interior planes and upland and hilly areas. The soils are mostly red loamy in composition with the interior plains consisting of alluvial soils and the coastal plains of sandy loam and red soils. The district experiences tropical monsoon type of climate with four distinct seasons i.e. a) hot weather season (March to May) b) south-west monsoon season (June to September) c) post-monsoon season (October to November) and d) cold weather season (December to February). The mean annual maximum and minimum temperatures of the district are 31.7^{o}C and 23.4^{o}C respectively. The average annual rainfall of the district is 1161.53mm with 70 to 80% of it occurring during south-west monsoon season i.e. June to September and the remaining occurs as a scattered rainfall during the post monsoon and hot weather seasons. The relative humidity of the district generally varies between 75 to 85 % all along the coast and often shoot up to more than to 85% during the monsoon season. The mean monthly normal wind speed of the district varies between 8.6 and 15.7 Kmph.

Reference Crop Evapo Transpiration (Eto)

It is the rate of evapo transpiration from a large area covered by vegetation. The most commonly used methods for the determination of ETo are the Penman-Monteith and Blaney-Criddle methods. The calculation of these ETo values take into consideration various climatic parameters like temperature, solar radiation, relative humidity, wind speed etc. The evaluation of ETo will help in the calculation of crop water needs and the management of irrigation systems. The calculated crop water needs can further be utilized to evaluate the individual crops sensitivity to droughts.

Crop Coefficient (K_c)

The effect of crop characteristics like variety, duration, growing season, stage of crop growth, depth of routing, method of irrigation, plant population, fertilization, plant protection, weed control etc. on crop water requirements is accounted by crop coefficients. For a selected crop, based on time of sowing, stage of development and the prevailing climatic conditions, crop coefficients can be determined using field experiments. These coefficients represent the water need of a crop growth under optimum conditions to produce maximum yield. The K_c values are same for any given crop period and change with the stage of the crop. Crop coefficient (K_c) together with ETo is used to estimate specific crop evapo transpiration rate. The resulting ET crop is used for the evaluation of irrigation water needs of the crops.

Data

The monthly minimum, maximum and mean values of temperatures for the period from 1955 to 2010 and the monthly normal values of sunshine hours, wind speed and relative humidity for a period of two decades of study area are obtained from Indian meteorological department. The crop yield data for the principal crops grown in the study area is

obtained for the period 2002 to 10 both in khariff and rabi seasons from the Directorate of Economics and Statistics, Government of Andhra Pradesh, Hyderabad. The crop coefficients (Kc) for all the principal crops are obtained for different growth stages of crops i.e. initial, crop development, mid season and late season/harvest stages from FAO Irrigation and drainage paper no: 56 (Richard G. Allen[2] et al. 1998), and from the literature on efficient use of irrigation water a(Sankara Reddy G.H[3] et al, 1995). The Crop periods (days) for all the principal crops grown in the district are obtained from the Agriculture Research Station, Ragolu, Srikakulam.

Determination of Reference Crop Evapo transpiration (ETo) Using Penman-Monteith Method

The monthly and yearly average values of Evapo transpiration are calculated in Penman - Monteith method using CROPWAT 8.0 taking into consideration the meteorological data comprising minimum, maximum temperatures, humidity, wind speed, sunshine hours etc.

The CROPWAT 8.0 calculates the reference evapo transpiration (ETo) using Penman-Monteith equation, assuming the reference crop evapo transpiration as the one from a hypothetical crop with an assumed height of 0.12m, having a surface resistance of 70 s/m, closely resembling the surface of green grass of uniform height, actively growing and adequately watered (Allen *et al*[2] 1998).

$$ETo = \frac{0.408 dR_n - G + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 U_2)} \quad (1)$$

Determination of Reference Crop Evapo transpiration (ETo) Using Blaney - Criddle Formula

Another set of Evapo transpiration values are calculated using Blaney - Criddle formula as stated below

$$ETo = p\,(0.46\, T_{mean} + 8) \quad (2)$$

T_{mean}= mean daily temperature (^{0}C)

$$T_{mean} = \frac{T_{max} + T_{min}}{2}$$

$$T_{max} = \frac{\text{Sum of all } T_{max} \text{ values during the month}}{\text{Number of days of the month}}$$

$$T_{min} = \frac{\text{Sum of all } T_{min} \text{ values during the month}}{\text{Number of days of the month}}$$

p= mean daily percentage of annual day time hours

Calculation of Irrigation Water Requirement using Penman- Monteith ETo's

The gross irrigation water requirement (IRR) is calculated using the following set of equations.

$$IRR = W_r \div 0.85 \text{ (for Paddy) (mm/month)} \quad (3)$$

$$IRR = W_r \div 0.65 \text{ (for the crops other than Paddy) (mm/month)} \quad (4)$$

Calculation of Irrigation Water Need using Blaney-Criddle Formula

The gross irrigation water need (IN) for various crops is determined using the ETo's calculated from using Blaney-Criddle formula, using the following equation.

$$IN = E_T\,Crop + SAT + PERL + W_L - P_e \quad (5)$$

$$E_T\,Crop = ETo \times K_c$$

RESULTS

The reference evapo transpirations (ETo's) are evaluated using the above cited data in both Penman-Montieth and Blaney-Criddle Method for the period 1955 to 2010.

The irrigation water requirements per hectare (IRR) for all the principal crops in the study area are calculated for the period 2001 to 2010 using Penman-Montieth ETo's and are presented in the following table 1. The zero value for IRR implies that there is no need of water to be supplied from tanks and the rainfall itself is sufficient for the growth of crops. Similarly, The irrigation water requirements per hectare (IN) for all the principal crops in the study area calculated for the period 2001 to 2010 using Blaney-Criddle ETo's are presented in the following table 2.

The average gross irrigation water requirements for the entire study area against the irrigated land of each principal crop are calculated for the total period 2001 to 2010 and are presented in the following table 3.

From the above mentioned tables it is evident that the gross irrigation water requirements evaluated in Blaney-Criddle method are found to be on lower side. Since, the Blaney-Criddle method includes parameters like percolation losses, water requirement for layer formation in case of paddy etc. The gross irrigation water requirements evaluated in this method though on lower side, are considered for the calculations of the average gross irrigation water requirement of the entire study area which accounts to 1,16,110.96 M.Cft /year.

Table 1: Irrigation Water Requirement IRR (mm) /Hectare Based on Penman-Monteith ETo's For the Principal Crops Grown in Srikakulam District

Name of the Crop	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Rice (kharif season)	1557.63	1832.55	1290.84	1699.2	1402.73	1450.42	1633.19	1653.68	1720.31
Rice (rabi season)	1778.92	1798.89	1747.93	1797.74	1797.16	1808.69	1807.69	1748.1	1780.28
Black gram (khariff)	0	36.1	0	0	0	0	0	0	0
Blackg gram(rabi)	258.7	391.45	349.99	391.52	347.16	399.8	398.67	390.12	384.22
Green gram (kharif)	0	0	0	0	0	0	0	0	0
Green gram(rabi)	201.34	334.31	291.14	334.34	285.11	339.33	336.88	329.54	330.21
Ground nut (kharif)	0	0	0	0	0	0	0	0	0
Ground nut(rabi)	317.67	449.76	396.11	449.05	409.67	461.26	458.86	405.65	396.98
Mesta	0	133.89	0	0	0	0	0	13.91	13.2
Sugarcane	594.12	1263.47	675.26	1069.92	836.42	692.74	735.85	1038.29	974.9
Horsegram	225.58	357.56	314.43	356.91	313.01	365.18	364.06	355.51	373.29
Sesamum (kharif)	0	0	0	0	0	0	0	0	0
Sesamum(rabi)	533.36	553.48	529.71	512.11	568.01	543.75	567.81	473.37	520.31
Sunflower	483.2	493.19	423.96	494.49	493.45	493.37	504.88	418.47	501.3
Bajra	0	69.74	0	0	0	0	0	0	0
Ragi (kharif)	0	114.67	0	12.53	0	0	0	0	0
Ragi (rabi)	468.95	483.52	411.316	482.57	486.16	482.66	493.15	409.7	470.65
Cashew nut	540.58	874.47	286.59	680.31	443.17	309.55	348.07	658.79	490.54
Maize(kharif)	0	0	0	0	0	0	0	0	0
Maize (rabi)	506.01	516.36	447.18	518.03	523.63	516.6	527.87	441.36	503.74
Cotton	0	51.33	0	0	0	0	0	0	0
Red gram	0	347.58	0	176.72	0	0	85.38	126.26	99.19
Jowar	0	31.59	0	0	0	0	0	0	0
Total	**7466.06**	**10133.91**	**7164.46**	**8975.44**	**7905.68**	**7863.35**	**8262.36**	**8462.75**	**8559.12**

Table 2: Irrigation Water Need in (mm)/Hectare Based on Blaney-Criddle ETo's for the Principal Crops Grown in Srikakulam District

Name of the Crop	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Rice(kharif season)	1553.09	1758.18	1396.67	1649.74	1468.20	1415.20	1429.00	1673.24	1576.31
Rice (rabi)	1585.00	1679.07	1634.72	1677.88	1657.25	1640.00	1687.00	1649.96	1712.53

Table 2: Contd.,

Blacg gram (kharif)	99.00	192.34	53.77	152.73	0.00	0.00	27.29	0.00	122.90
Blackg gram (rabi)	241.50	326.33	301.43	325.76	301.00	330.00	331.50	324.16	324.91
Green gram (kharif)	39.81	131.53	0.00	92.93	0.00	0.00	0.00	0.00	0.00
Green gram (rabi)	192.07	275.13	251.72	276.02	247.28	279.34	279.77	274.51	267.91
Ground nut (kharif)	4.00	144.92	0.00	27.62	0.00	0.00	0.00	0.00	98.96
Ground nut(rabi)	285.09	369.56	337.88	368.64	346.73	354.13	375.24	341.22	381.93
Mesta	160.00	355.42	0.00	250.20	70.00	0.63	29.00	271.00	229.09
Sugarcane	943.18	1178.58	805.05	1054.10	902.94	781.30	835.28	1038.19	981.04
Horsegram	213.00	326.38	301.43	326.03	301.00	330.00	332.00	324.16	329.31
Sesamum (kharif)	0.00	76.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sesamum(rabi)	402.00	418.37	447.29	391.38	427.00	384.00	424.54	381.59	390.61
Sunflower	380.07	388.74	347.00	388.86	395.00	346.00	394.15	350.05	370.12
Bajra	105.00	250.69	0.00	139.59	0.00	0.00	84.78	102.00	90.53
Ragi(kharif)	0.00	216.92	0.00	151.21	0.00	2.00	14.00	167.00	140.12
Ragi(rabi)	375.00	385.16	342.45	384.00	389.23	340.00	390.00	342.99	360.18
Cashew nut	699.00	922.61	548.00	797.00	622.00	526.00	581.00	787.20	623.15
Maize(kharif)	97.00	162.65	121.00	127.00	8.00	0.00	0.00	0.00	10.00
Maize (rabi)	396.86	405.32	363.68	406.00	412.00	362.29	411.19	368.27	354.12
Cotton	177.38	299.19	0.00	174.33	43.38	0.00	0.00	215.62	180.34
Red gram	242.92	463.40	0.00	359.99	106.73	153.25	423.01	328.65	345.23
Jowar	73.00	217.38	0.00	107.10	0.00	0.00	52.00	68.00	127
Total	**8263.96**	**10943.93**	**7252.08**	**9628.11**	**7697.74**	**7244.14**	**8100.74**	**9007.81**	**9016.29**

Table 3: Gross Irrigation Water Requirements for the Principal Crops Grown in Srikakulam District

Sl. No.	Name of the Crop	E_t Crop (Using Penman-Montieth Eto) mm	E_t Crop (Using Blaney-Criddle Eto) Mm	Irr(Using Pemman-Monteith Eto) M.Cft.	In(Using Blaney Criddle Eto) M.Cft.
1	Rice (kharif season)	626.35	969.00	98664.12	97097.39
2	Rice(rabi season)	531.12	622.72	1434.50	1328.31
3	Blacg gram (kharif)	258.15	427.50	0.22	6.48
4	Blackg gram(rabi)	226.85	327.78	4983.92	4212.28
5	Green gram (kharif)	218.85	415.99	0.00	4.55
6	Green gram(rabi)	216.67	277.10	3174.74	2681.56
7	Ground nut (kharif)	309.96	472.76	0.00	229.70
8	Ground nut (rabi)	293.70	368.97	956.72	791.14
9	Mesta	519.19	788.46	119.23	699.91
10	Sugarcane	1278.24	1636.14	3436.42	3933.22
11	Horsegram	233.15	324.26	1353.45	1286.85
12	Sesamum (kharif)	296.14	402.00	0.00	7.03
13	Sesamum(rabi)	366.81	401.37	825.42	632.02
14	Sunflower	323.96	387.88	51.43	43.02
15	Bajra	368.11	560.04	10.70	89.79
16	Ragi (kharif)	307.55	436.20	11.13	40.72
17	Ragi (rabi)	316.35	379.44	187.88	148.43
18	Cashew nut	1027.27	1073.35	2013.34	2508.10
19	Maize(kharif)	306.46	506.50	0.00	17.37
20	Maize (rabi)	339.08	404.95	174.73	136.94
21	Cotton	465.22	731.38	3.45	73.10
22	Red gram	544.49	779.04	47.78	135.52
23	Jowar	343.76	541.00	0.50	6.75
Total Average		**9717.43**	**13233.80**	**117449.63**	**116110.96**

IRR: Gross Irrigation Water requirements (Based on Penman-Monteith ETo's)
IN: Gross Irrigation Water requirements (Based on Blaney-Criddle ETo's)

CONCLUSIONS

- The average gross irrigation water requirements for the entire study area against the irrigated land of each principal crop are evaluated for both khariff and rabi seasons using Penman-Monteith and Blaney-Criddle ETo's.
- The average annual gross irrigation water requirement evaluated in Blaney-Criddle method for all the principal crops put together amounts to 1,16,110.96 M.Cft.

- However, the water available for irrigation requirements from all the 7,721 tanks of Srikakulam district is only 30,295.95 M.Cft (Source: O/o Executive Engineer, I & CAD, Irrigation Division Srikakulam). This shows that the water available for irrigation purposes under tank irrigation in the entire district is only 26.09% of the required quantity.
- Since tanks are the major source of irrigation water requirements in Srikakulam district and as they could provide only 1/3rd of the gross irrigation water requirement, the irrigation potential of the district is decreasing year after year. Therefore, it is suggested that the capacities of the tanks are to be increased to restore the minor irrigation potential of the district.

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